

Conference Paper

Mineral Concentrates As a Factor of the Khibiny Apatite-Nepheline Ores Efficiency Improvement

A. I. Nikolaev¹, L. G. Gerasimova¹, A. I. Kalugin², B. V. Levin³, and G. O. Kalashnikova⁴

¹Tananaev Institute of Chemistry – Subdivision of the Federal Research Center "Kola Science Center of the Russian Academy of Sciences", Russia

²JSC Apatit, Kirovsk, Russia

³JSC NIUIF, Moscow, Russia

⁴Federal Research Centre "Kola Science Centre of the Russian Academy of Sciences", Russia

Abstract

Apatite-nepheline ores of the Khibiny deposits contain the largest phosphorus-bearing resources in the world, and, at the same time, they contain associated valuable components in the rock-forming minerals — apatite, nepheline, sphene and titanium magnetite. Intensive development of the Khibiny deposits with production of only apatite concentrate and a small part of nepheline concentrate resulted in the accumulation of over 1.0 billion tons of wastes in tailing storage facilities and dumps during 90 years of JSC Apatit operation. The possibility of increasing the efficiency of the use of the main concentrates of apatite-nepheline ores of the Khibiny deposits and wastes for their processing is considered through the use of technological developments of the FRC KSC RAS, JSC RIFI and JSC Apatit to obtain traditional and new target products. A fundamentally new approach to the problem of sustainable use of natural resources is focused on establishment of the whole production chain in the region, from mining and processing operations to manufacturers of final high technology products (rare-earth products, welding and construction materials, coloring agents and other materials). They also determine the level of industrial technical progress.

Keywords: Khibiny apatite-nepheline ores, mineral raw materials, extraction and processing, new materials

Corresponding Author:

A. I. Nikolaev

nikol_ai@chemy.kolasc.net.ru

Published: 31 December 2020

Publishing services provided by
Knowledge E

© A. I. Nikolaev et al. This article is distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use and redistribution provided that the original author and source are credited.

Selection and Peer-review under the responsibility of the TECHNOGEN-2019 Conference Committee.

OPEN ACCESS

The Kola Peninsula is a large mining complex satisfying the national demands in various types of mineral resources. The mining operations of the region produce up to 200 million tons of solid wastes, and consume up to 2 billion cubic meters of fresh water. At the same time, mining waste recycling does not exceed 3-4% of the mined rock mass. More than 6 billion tons of crushed or ground rock mass are accumulated in waste dumps and tailing storage facilities. Additional problems are often caused by complex ores containing several commercial components in one or several minerals. Such problems relate to imbalances of sale market for all potential products of complex

ores processing, rather than difficulties in the processing technology implementation. This statement fully characterizes apatite-nepheline ores (ANO) of the Khibiny deposits. These deposits contain the largest phosphorus-bearing resources in the world, and, at the same time, they contain associated valuable components in the rock-forming minerals — apatite, nepheline, sphene and titanium magnetite. Average mineral composition of the ANO is shown in table below.

TABLE 1: Mineral composition of the Khibiny apatite-nepheline ores.

Mineral	Mineral content, %	Valuable components
Apatite	28.0-35.0	P ₂ O ₅ , REM, F ₂ , SrO
Nepheline	35.0-45.0	Al ₂ O ₃ , Na ₂ O, K ₂ O, Ga, Rb, Cs
Aegirine	8.0-12.0	
Sphene (titanite)	2.0-3.5	TiO ₂ , REM, Nb ₂ O ₅ , SrO
Titanium magnetite	1.0-1.5	Fe ₂ O ₃ , TiO ₂ , V ₂ O ₅

The ANO deposits were discovered by the Northern scientific field expedition of the Academy of Science of the USSR under the leadership of academician A. E. Fersman in 1923–1926 [1]. The deposits development started 90 years ago. During all these years, the ANO deposits were the main sources for production of a wide range of phosphorous-bearing products in the USSR, and then in Russia. In the 80s of the last century, apatite concentrate (AC) production reached 20 mtpa, currently — about 10 mtpa. Most of the AC is produced by JSC Apatit of the FosAgro Holding. Parallel AC production appeared in JSC SZFK (North-West Phosphorus Company) of the Acron Holding in 2013.

For ANO processing, A. E. Fersman was the first to propose the principle based on the theory of academician V. I. Vernadsky developed in the beginning of the 20th century. The theory describes a sphere unifying the humankind — noosphere, which combines nature and society, science and government policy, interests of countries and peoples. According to the RF President V. V. Putin, it is the noosphere concept that actually forms the basis of sustainable development.

It was planned to develop the Khibiny mining complex based on the Soviet scientists' achievements, while using all rock mass, minimum imported resources, and producing high-quality products without any wastes. In his report at the USSR Gosplan Conference, A. E. Fersman presented a scheme for multipurpose utilization of the main mineral resources mined in the Khibiny and Moncha tundras in the system of the Northern Mining and Chemical Operations Group "Apatit" by the end of the second five-year plan (1937) described in the paper prepared by G. N. Solovyanov [2].

Apart from the main operation of the Apatit Group in the town of Khibinogorsk, it was planned to establish production sites in the town of Kandalaksha that had a hydraulic power plant, a railway terminal and a seaport on the White Sea coast; and

in the Moncha tundra, where magnetite and sulphide copper-nickel ores deposits had just been discovered. All three operations were tightly connected with engineering communication system. The range of final products was very wide, focused on long-term requirements of a young economy of the republic. Apart from mineral concentrates (apatite, nepheline, sphene, magnetite, copper-nickel, pyrrhotine etc.), the main products included also phosphorus fertilizers, thermophosphates, yellow phosphorus, ferrophosphorus, phosphoric and sulfuric acids, liquid glass, alumina, cement, concentrate of rare metals, and many others [2]. Moreover, the planned production scale of some products shall reach from thousand tons per year up to million tons per year. Unfortunately, the plans for Apatit Group development were frozen. However, it did not stop studies of the Arctic resources multipurpose utilization implemented by the Academy of Science of the USSR.

Intensive development of the Khibiny deposits with production of only apatite concentrate and a small part of nepheline concentrate resulted in accumulation of over 1.0 billion tons of wastes in tailing storage facilities and dumps during 90 years of JSC Apatit operation. At the same time, many technologies of the main concentrates recovery from ANO and their processing were tested at pilot scale, and confirmed that all valuable components can be recovered in the form of commercial products, and overburden rocks and processing waste can be used as constituents of construction and technical materials. However, implementation of the technologies is postponed due to various reasons [3, 4]. The problem of production scale with full utilization of resources is the most complicated one, as the volumes of high-demand commercial products determine waste scale. For example, full-scale processing of nepheline concentrates exceeds the market demand in the main products, and small-scale processing appears to be economically inefficient. Besides, actual demand in new products at the domestic market, even for strategic materials, remains low due to general condition of the national industry.

During AC processing, REM and strontium compounds associated with the state reserves are not recovered. With REM content 1% as recalculated to their oxides, and AC production over 10 mtpa (JSC Apatit and JSC North-West Phosphorus Company), over 100 thousand tons of REM oxides are annually written off the state reserves. This amount can cover the domestic market demand in such compounds many times. During the last five years, three pilot operations were established for REM collective concentrates production during AC processing, based on sulfuric-acid and nitric-acid process flow diagrams in Cherepovets, Voskresensk and Velikiy Novgorod [5, 6]. All three operations proved a possibility for high-grade REM concentrate recovery; but such products appeared to be of no demand at the domestic market. The corresponding industrial

operations can be established only in case of the market demand or government order for REM products, with account to market requirements to their quality and quantity, as well as requirements of the national defense industries.

Small portion of nepheline concentrate recovered from ANO is used for production of alumina, cement and sodium products. Despite the proven fact that it is technically possible to recover rear metals associated with the state reserves — Rb (up to 177 g/t), Ga (up to 49 g/t), Cs (up to 4.0 g/t) — from nepheline, their recovery is not economically efficient. Therefore, such rare elements shall be excluded from the state reserves, or the government shall allocate investment support to the corresponding operations with account to the defense industry complex.

Another two potential titanium-containing concentrates recovered from the ANO (sphene and titanium magnetite) can be used without processing as natural alloy components of welding materials, and for production of environmentally safe titanium tanning material for leathers, non-organic titanium-containing sorbents for liquid radioactive waste (LRW) processing and purification of heavy-metal effluents, photochemically active titanium dioxide, coloring agents and aggregates, sealants for aerospace industry, vanadium compounds, and other products. Every year about 100 thousand tons of titanium dioxide are lost with these two unrecoverable potential concentrates in waste dumps. The market demand in many products mentioned above can be satisfied by a low-tonnage production [7, 8]. Due to urgent problem related to recycling of LRW accumulated in the country since the Soviet times, we need to search for modern and more safe technologies for the waste processing and disposal, in particular, by using advanced titanium-containing sorbents produced from sphene.

A fundamentally new approach to the problem of sustainable use of natural resources, including ANO, is focused on establishment of the whole production chain in the region, from mining and processing operations to manufacturers of final high technology products. The latter determine the level of industrial technical progress. This approach shall enable not only to save high resource potential of the region, but also to raise it to a new level ensuring entry into the Russian as well as foreign markets, primarily, the market of rare-earth products, welding and construction materials, coloring agents and other materials. Implementation of the integrated resources processing can become a basis for production diversification and establishment of a network of small operations based on public-private partnership. One of the initial stages of the accelerated implementation of such approach is establishment of the Kola Chemical and Technological Cluster (KCTC) for receiving and processing of the regional resources, and production of functional materials demanded by the industry [7, 8]. Establishment of such cluster initiated by the Kola Scientific Center of the Russian Academy of Sciences

was supported by the regional government, mining and processing companies and regional universities.

In addition to solution of purely technical issues, it is necessary to develop a consistent program of the inter-industrial balance of production and demand in mineral concentrates and products based on them. Such program will enable to plan the scale of mineral concentrates production from ANO and processing capacity with account to economic characteristics and actual demand in new products at the external and internal markets.

Today it is obvious that the government and business alone can not manage integrated commercial implementation of new complex technologies due to long lead time of such projects, high financial risks and long payback period. Therefore, the government, business, science and education shall join their efforts. This is exactly what enables to create necessary conditions for new economically efficient operations complying with the latest world environmental standards.

Business initiates commercial development of the regions with the government support by providing long-term loans with low interest rates, and encouraging the business with other taxation schemes. The science and education objectives are establishment of constantly updating and growing highly efficient scientific researches and human resources for their implementation. Now it is time to begin implementation of the latest and efficient technologies focused on increase of the range of mineral concentrates recovered from apatite-nepheline ore, broadening of the products sale markets, increase of economic efficiency of mining and processing determining sustainable development of operations, regions, and the whole country.

Funding

The research is supported by the Kola Science Center of Russian Academy of Sciences (0226—Institute of Chemistry-2019-0011) and the Russian Foundation for Basic Research (18-29-12039).

References

- [1] Fersman, A. E. (1932). *Multipurpose Utilization of Mineral Resources*. Leningrad: AS USSR.
- [2] Solovyanov, G. N. (1932). *Scientific Base of the Khibiny Mining Complex*. Leningrad: ONTI.

- [3] Kalinnikov, V. T. and Grigoryev, A. V. (1999). Integrated Processing of Apatite-nepheline Ores: Current State and Development Trends. *Integrated Processing of Apatite-nepheline Ores*, Apatity, KSC RAS, pp. 5–15.
- [4] Fedorov, S. G., et al. (2004). *Chemical Processing of Mineral Concentrates of the Kola Peninsula*. Russia: Apatity.
- [5] Lokshin, E. P. and Tareeva, O. A. (2015). *Technologies Development for the Extraction of Rare Earth Elements while Sulfuric Acid Processing of the Khibiny Apatite Concentrate for Mineral Fertilizers Production*. Russia: Apatity.
- [6] Polyakov, E. G., Nechaev, A. V. and Smirnov, A. V. (2018). *Metallurgy of Rare Metals*. Moscow: Metallurgizdat.
- [7] Nikolaev, A. I. and Krivovichev, S. V. (2019). Prospects for the Development of the Kola Chemical Technological Cluster in Transition from a Resource-Based Economy to an Innovative Economy. *Theoretical Foundations of Chemical Engineering*, vol. 53, issue 5, pp. 980–985.
- [8] Nikolaev, A. I. (2018). Studies of Tananaev Institute of Chemistry - Subdivision of the Federal Research Centre “Kola Science Centre of the Russian Academy of Sciences” for the sustainable development of chemical industry in the Russian Arctic. *Transactions Kola Science Centre*, issue 1/2018 (9) (part 1), Chemistry and Materials, series 2, pp. 80-84.